Mobile Applications and Cloud Computing Applied on a Solution to Optimize the Auscultation Process

Paulo Estevão de Oliveira Ferreira, Daniel Alberto Santos Divino, Gabriella Braga Garcia Santos, Gustavo Ferreira Lins do Rego Santos, Lais Pimenta Lopes, Renato Alcântara Bento Raphael, Ricardo Barbosa Soares, Suellem Andrade Dutra, Wilgner Ricardo Rail Silva, Vladimir Alexei Rodrigues Rocha, Gustavo Alves Fernandes, Luiz Melk de Carvalho, Bráulio Roberto Gomes Marinho Couto, Diva de Souza e Silva Rodrigues, Flávio Henrique Batista de Souza

Centro Universitário de Belo Horizonte UNIBH, Brazil

*Corresponding author

Abstract.

Auscultation measurement is one of the primary processes of medical education. Despite its extreme importance, the number of patients who are delegated to students for their care depends on the frequency of patients at the clinic where they perform their practices, which may be sufficient or not (in the pandemic period of COVID-19, the Brazilian hospitals had a high demand for professionals in the medical field, emptying school clinics). In addition, it is relevant for the teachers to compare the auscultation diagnosis that their students made with the signal that was actually collected in the process. This work proposes a method that aims to assist the teaching of cardiac auscultation techniques in medical courses, as well as to generate a structure that can share the measurements, in addition to recording them via Cloud Computing for further evaluation by the teacher. To achieve this goal, this project aims on developing two applications: a web and a mobile application. The mobile application is responsible to capture the sounds generated during the auscultation process using a hardware adapted on a stethoscope and a microphone. The audios collected are saved in the cloud using the Cloud Firestore platform and can be accessed through both web and mobile platforms. The framework also enables the implementation of a data analysis tool for medical teaching strategies.

Keywords: Cardiac Auscultation; Mobile Application; Cloud Computing; Medical Education; Data Analytics.

1. Introduction

Mobile learning has been transforming the ways of teaching and providing a new field of research for the subject. Thus, many researches have been emerging to identify new ways of learning that are quick and easy to access, providing activities that help students in their learning process, as stated in (Mao, 2014).

Learning systems and environments have shown increasing importance in recent years, being fundamentally applied in teaching and training in academic and industrial environments.

Mobile educational systems and applications have been developed to help students to learn in varied areas of knowledge (Duarte Filho et al., 2015).

The popularization of mobile devices, such as smartphones and tablets, provides new ways to apply mobile learning. It is known, above all, that technologies represent an opportunity to promote changes in education, especially in relation to teaching practice, from teacher-centered to student-centered, to meet their knowledge demands. In this sense, mobile technologies can provide gains to the process, because with them, it is possible to learn anywhere, anytime and in many ways (Alharbi, 2021).

According to Stergiou et al. (2018), Mobile Cloud Computing integrates multiple technologies to maximize the capacity and performance of existing infrastructures. This technology can be defined as an integration between cloud computing and mobile devices, aiming to enable mobile devices in terms of computing power, memory and storage. A new generation of services is being built based on the concept of cloud computing with new ways to provide access to information and data anywhere and anytime without the need for hardware equipment.

The use of technologies applied in the health area has a great relevance on providing several tools and resources to help professionals and students in the area and, mainly, to provide opportunities for improvements in an information network between patients, systems and health professionals (Gonçalvez et al., 2016).

According to Melo and Damasceno (2006), the conventional methods adopted in teaching breathing sounds auscultation have not been efficient. Cardiac auscultation is one of the most difficult clinical skills to learn by medical students. This is mainly because the stethoscope is an individual instrument, which makes it difficult to practice during student learning.

The technical reproduction of auscultation in the cardiovascular system following the theory taught by semiology books and professors is not easily reproduced by students who, even understanding the various semiological sounds of the cardiovascular system, cannot identify them due to lack of practice and technique.

If the experience of cardiac auscultation could be acquired during academic training, it would be possible to improve the efficiency and quality of medical services provided in college clinics, in addition to inducing a significant and relevant improvement in the quality of Brazilian medical care.

This project aims to collect, record and store in the cloud the auscultation sounds captured during the consultation carried out by the student. An adapted stethoscope is used to capture the sound of auscultation and a mobile application to manipulate the generated audio.

Within the perspective presented, this article discusses the proposal for developing a mobile application. The aim of this project is to contribute to the improvement and academic qualification of students in Medicine, more specifically, in Cardiac Auscultation. The aim is to develop a solution, supported by a mobile application and a web application, which can be purchased by Brazilian medical students to be used on their smartphones.

2. Materials and Methods

2.1 Assessment of Heart Auscultation Concepts

According to Silva et al. (2018), cardiac auscultation is the capture of the last phenomenon of the cardiac cycle. Auscultation is only possible because of the propagation of vibrations produced by the cardiovascular system to the surface of the body. Although these vibrations propagate in all directions, there are specific regions where the intensity of the waves are greater. These points are called cardiac auscultation foci.

The audible frequency of these vibrations is, in general, for the human being, in a range that varies between 30Hz to 18kHz and the sounds perceived through common stethoscopes have low amplitude (in a frequency range from 20 to 500Hz) (Silva et al., 2018).

The cardiac auscultation technique was the focus of this work to capture heart sounds. The results have been collected through this procedure and stored in the cloud to be available to the users.

Medical professors and students classify the teaching of cardiac auscultation as fundamental in medical training. It is known that teaching through theory alone is not very effective in improving the recognition of heart murmurs. On the other hand, teachings that include repetitions of heart sounds were able to increase the proficiency of students in training (Mesquita et al., 2013).

2.2 Related Work Analysis

Among the related works that address technologies such as cardiac auscultation, mobile learning and cloud computing there is the work developed by Stergiou, et al. (2018), who studied the integration of cloud computing with the Internet of things and showed its cloud storage capabilities.

The work of Da Costa et al. (2018), which is an article that presents a view of how mobile learning has been modifying education and providing a new experience in the learning of human anatomy. And finally, Gonçalves et al. (2016) presented a proposal for the development of a system to capture and store data related to heart rate.

2.3 References Concepts

Some concepts are outlined due to its importance for the present research:

Cloud Computing: can be defined as an infrastructure paradigm that provides web-based and on-demand services. Resources are provided by the pay-per-use model (Users only pay for the resources used) (Ghahramani et al., 2017). The developed application of the present work uses cloud computing to store the collected data.

Mobile solutions: according to Alharbi (2021), the use of mobile devices applied in teaching and learning processes, used by medical students and their medical professors, has the potential to enhance and streamline the teaching/learning process. The use of apps is increasingly present in the daily lives of health professionals, bringing several benefits due to being an easily accessible and practical tool, which brings learning at the right time, increases opportunities and study time, makes more efficient work and quality of service.

Development Frameworks: for the development of the work, the following frameworks were used:

- React Native: is a Framework for creating native mobile applications for iOS and Android (Eisenman, 2015).
- Firebase: is a BaaS (Backend as a Service) for Google's Web and Mobile applications (Moroney & Moroney, 2017).
- Cloud Firestore: is a flexible and scalable database for mobile device, web and server development from Firebase and Google Cloud Platform according to Fire Base (S.d.).
- JavaScript: it controls the browser, communicates asynchronously with the server, dynamically alters the content of a web page, in addition to being used in the development of games and applications (Novick, 2017).
- NPM (Node Package Manager): is a repository provided with Node.js that provides a set of publicly available reusable components.
- HTML (HyperText Markup Language): it is a language for hypertext markup through tags (Novick, 2017).
- CSS: is called Cascading Style Sheet language and is used to style elements written in a markup language such as HTML (Novick, 2017).

All the previous concepts and technologies were the basis for the development of the solution proposed in this work.

2.4 Methods

During the development of this work, an exploratory research was carried out to identify the main challenges in learning auscultation techniques.

The methodology was divided into two stages:

- **Step 1:** Hardware adaptation for cardiac auscultation capture. The hardware consisted of an adapted stethoscope with a microphone allowing the sounds of the auscultation to be recorded directly as audios in mobile devices.
- **Step 2:** Development of a mobile and web application as an auxilliary tool to help on teaching the cardiac auscultation technique. The application can capture auscultation through adapted hardware and store it in the cloud, making it available for both: the student who performed the procedure and the responsible teacher. Once saved, the sounds are kept available in the web application.

3. Results

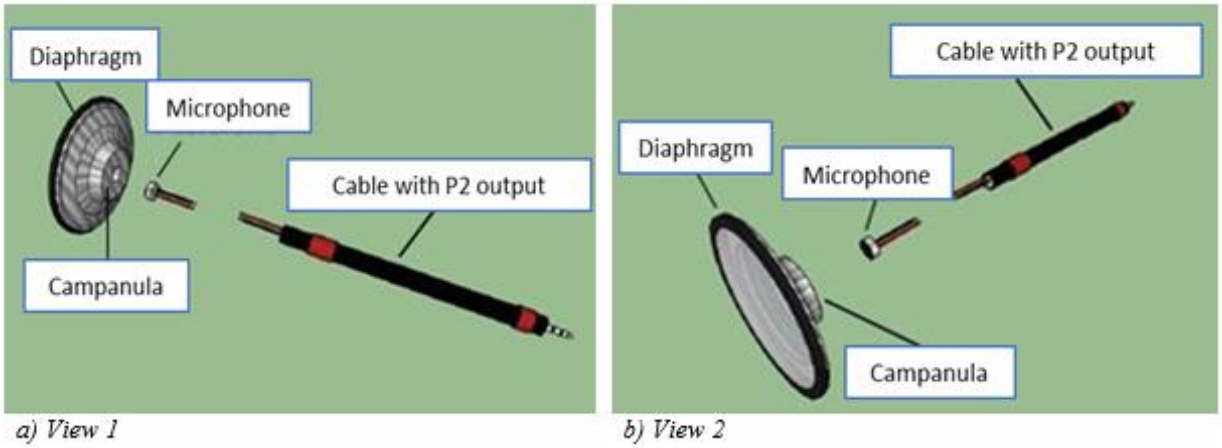
3.1 Hardware Adaptation

The auscultation capture hardware was developed, as shown in Figure 1. The hardware is composed of a mechanical component created by the diaphragm membrane which is responsible for the amplification of the heart sounds transmitted through the body surface at

specific auscultation points. The materials used during its assembly were: Bell of a stethoscope; 3.5mm 4-pin P2 output cable with connector plug and microphone input.

The microphone is located at the confluence of the hood output, the first electronic component, which is connected by a P2 type input cable with four components. The first component (base) of the connector pin is responsible for conducting the captured sound noises through the microphone.

Figure 1: Hardware Development.



a) View 1 *b) View 2*

Source: Authors, 2021

3.2 Mobile Application

A mobile solution was developed as an interface for the hardware system of data aquisition to help on the teaching process of the cardiac auscultation technique to medical students.

Inittialy, to establish the work flow and development of the application, it was necessary to identify which agents that would be involved in the process.

In the developed application it is intended that the student has the option of recording cardiac auscultations, listening to previously stored records and deleting them. For the teachers, the application allows them to have access to the records of all students who are enrolled in the subject.

Auscultation is captured through a stethoscope connected to a headphone, simulating the recording of an audio. In Figure 2, the sequence of activities that must be performed by the application to support the user is shown.,. In accordance with the activity flow shown in Fig. 2, in Figure 3 is shown the structure in which the interface of the application (screens) were organized.

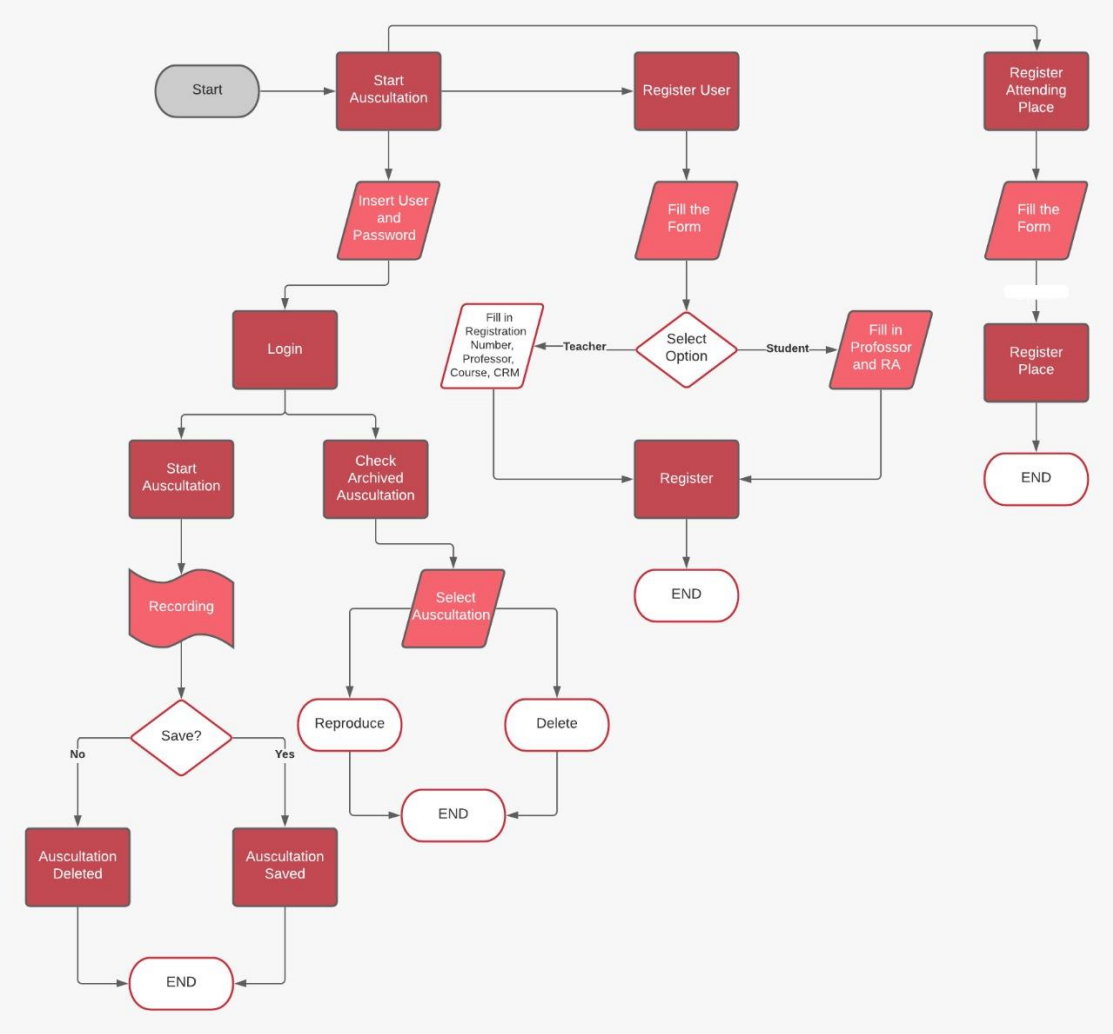
The system operation flow starts at the login screen where the user already registered must enter their email and password. If the user does not have a registration, they can register, when entering the system, and the permission group to which that user belongs will be checked:

- **Student user:** the user of the student group has permissions to record, reproduce and delete the sounds made by them.
- **Teacher user:** the teacher group user is allowed to reproduce the sounds made by all students enrolled in the classes they teach, in addition to recording, reproducing and deleting the sounds made by them.

Thus, with these prerogatives respected, the flow of using the application begins.

When the application is started, it displays a screen (Appendix I – Screen 1) responsible for controlling the access to the tool, which is done by means of a username and password. By clicking on the "Login" button at the bottom of the same screen, the user information is submitted to a validation step, through the records in the database.

Figure 2: APP activity sequence



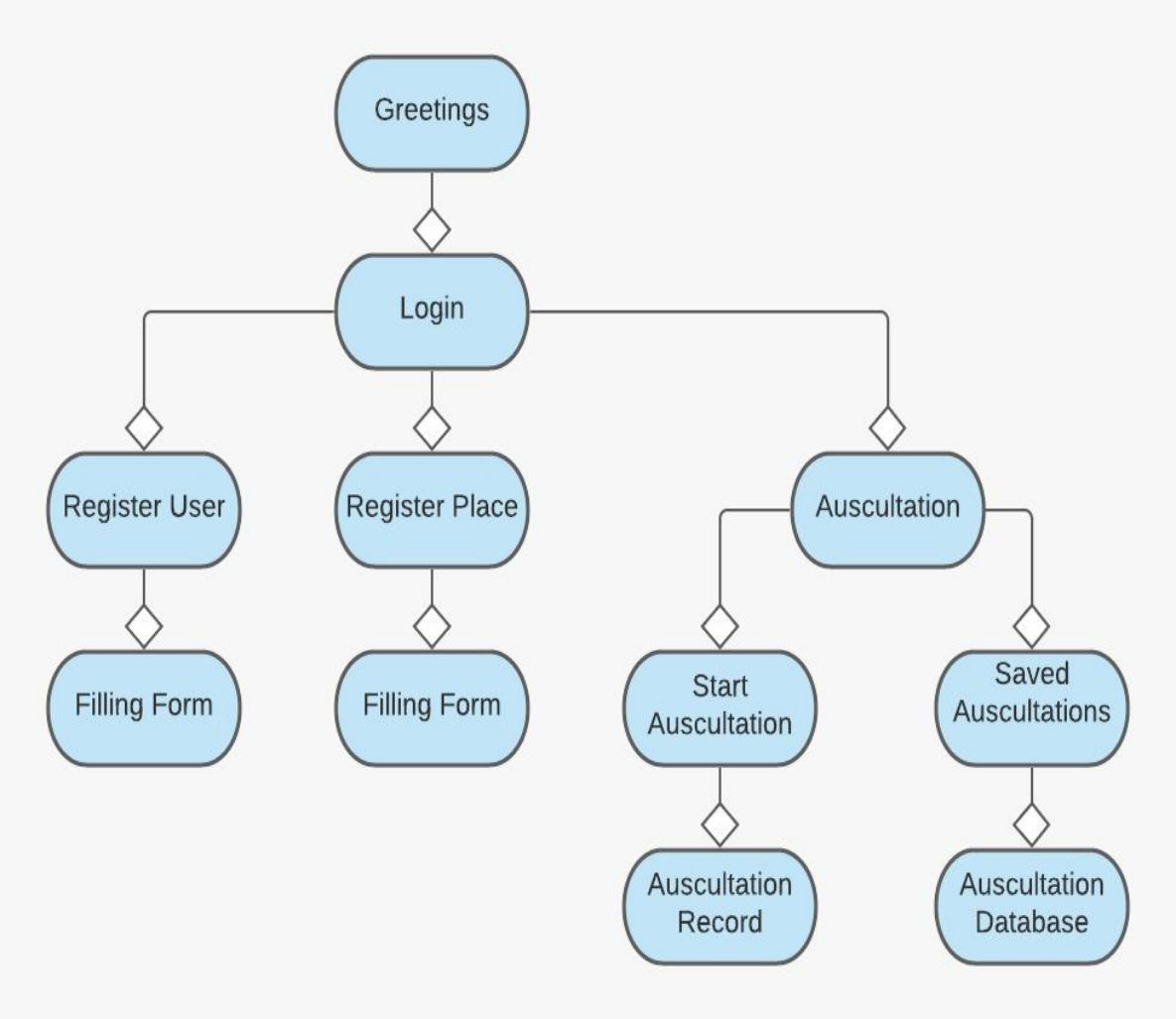
Source: Authors, 2021

After completing this validation successfully, the dashboard (Appendix I – Screen 2) is displayed, which is enabled for the user in question based on the user's permissions.

If the user does not have a registration, on the same screen is found the option to "Register User" where it is possible to register new users in the system via a database (Appendix I – Screen 3). At this point, the user is asked to provide their identification data, which consists of Name, Login, Email and Password.

After that, one of two options are available: teacher or student (Appendix I – Screen 4). If the teacher is selected, specific information for this type of user will be requested (Appendix I – Screen 5), namely: teacher registration, teaching subject and CRM. If the student option is selected (Appendix I – Screen 6), the following information are selected: teacher and enrollment (RA).

Figure 3: APP structure diagram



Source: Authors, 2021

At the end of the login, the auscultation screen will be displayed where all the auscultations (Appendix I – Screen 8) made by the student are available. In the case of a teacher, the consultations are shown according to the classes they are teaching. On the initial screen, when selecting the option "Register a new Service Location", (Appendix I – Screen 1), it is possible to register new locations where the auscultation procedures can be carried out (Appendix I – Screen 7).

3.3 WEB Application

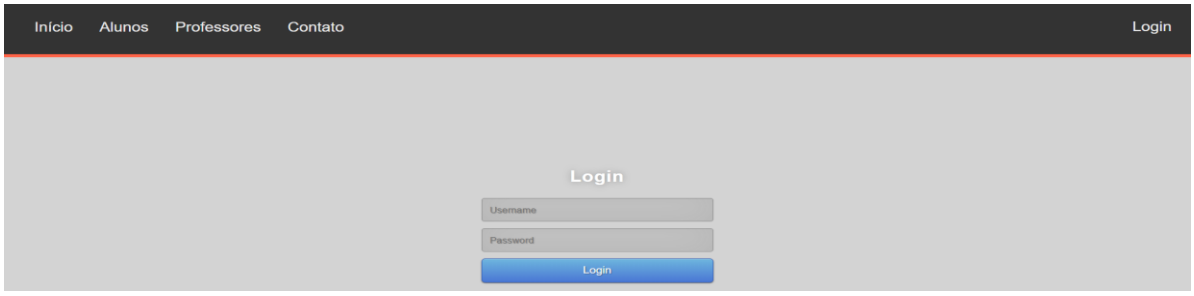
A web application was developed for consultation and monitoring of records made in the mobile structure by students and teachers. To have access to these files, the user must provide the email and password entered during the registration made in the application.

The auscultations are available in a similar way to the mobile device, where the student has access to all the auscultations that they registered and the teacher has access to all the records of the students enrolled in their class. In Figure 4, it is possible to observe the login screen, which is the only means available for the user to access the platform. In Figure 5 and 6 it is shown the records query.

As already mentioned, tools from the FireBase development platform were used to carry out this project. The storage of user data is performed through Realtime Database. This tool allows the storage and synchronization of data between other users and devices in real time with a NoSQL database hosted in the cloud.

Firebase Auth provides several authentication methods such as Facebook, Google or email/password. This tool is used to store user data and perform login authentication. For storage of audio files created from cardiac auscultation, the Cloud Storage tool is used. This tool has the function of storing and making available content generated by the user. In addition, Cloud Storage contains SDKs that add Google security to file uploads and downloads.

Figure 4: Login Screen

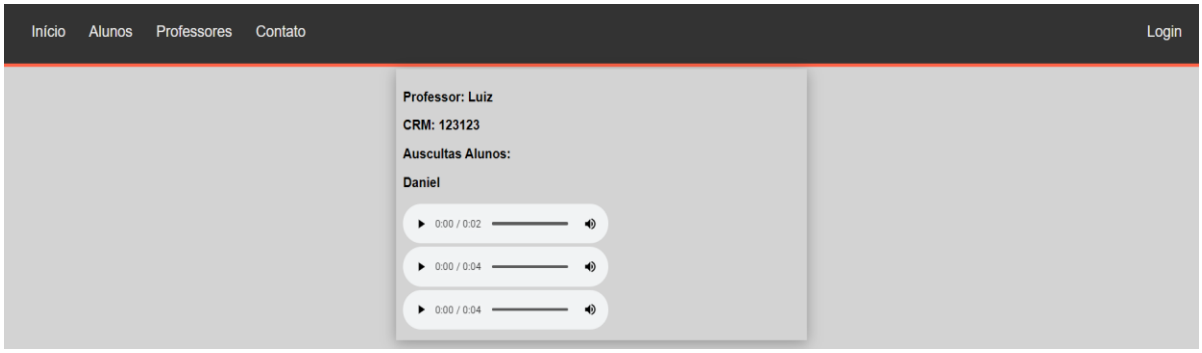


Source: Authors, 2021

Figure 5: Student Records Screen

Source: Authors, 2021

Figure 6: Teacher Records Screen



Source: Authors, 2021

This storage allows the management of auscultation teaching, since the teacher can listen and evaluate the collection of their students, as often as necessary.

4. Conclusion

The present study aimed to optimize the teaching of the auscultation technique, as well as generate a cardiac auscultation datasheet through a cloud storage system of data generated by users. Based on the results obtained, it was found that it is possible to optimize the teaching of the auscultation technique, as the student can use the sounds of a correctly executed auscultation as a basis for studies, if they have been recorded in the application.

Recordings are available at any time as long as the user has access to the smartphone or the internet. Different from the services available in the literature, this work offers an integration between an adapted, low-cost stethoscope and a mobile system that is compatible with most smartphones, making it accessible to most students.

References

Alharbi, B. (2021) Mobile Learning Age: Implications for Future Language Learning Skills. *Psychology and Education Journal*, v. 58, n. 2, p. 862-867.

Da Costa, R. D. A.; Almeida, C. M. M.; Nascimento, J. M. M. and Lopes, P. T. C. (2016) Anato mobile: Desenvolvimento colaborativo de um sistema de aplicativos para o ensino e a aprendizagem em anatomia humana em cursos superiores da área da saúde. *Acta Scientiae*, v. 18, n. 2.

Duarte Filho, N. F., Conrado, G. A. T., Lima, H. F. L. and Barbosa, E. F. (2015) Semes: Um Sistema Educacional Móvel para o Ensino de Engenharia de Software. *RENOTE-Revista Novas Tecnologias na Educação*, v. 13, n. 1.

Eisenman, B. (2015) Learning react native: Building native mobile apps with JavaScript. O'Reilly Media, Inc.

Fire Base. *Cloud Storage*. Available in: https://firebase.google.com/docs/storage?hl=pt-br Access in: 13 may 2021

Ghahramani, M. H.; Zhou, M. C.; Hon, C. T. (2017) Toward cloud computing QoS architecture: Analysis of cloud systems and cloud services. *IEEE/CAA Journal of Automatica Sinica*, v. 4, n. 1, p. 6-18.

Gonçalves, R. Y. L., Costa, W. L. B., Batista, F. W. P., Moreira, L. R., de Albuquerque, V. H. C., Bezerra, J. C. C. and Meireles, A. M. R. (2016). Desenvolvimento De Sistema De Monitoramento Da Frequência Cardíaca Com Uso De Hardware Livre E Integração Mobile. *Revista Mundi Engenharia, Tecnologia e Gestão*, ISSN: 2525-4782, 1(1).

Mao, C. (2014) Research on Undergraduate Students' Usage Satisfaction of Mobile Learning. Creative Education, Delaware, v.5, p.613-618.

Mesquita, C. T., Reis, J. C. R., Simões, L. S., Moura, E. C. M., Rodrigues, G. A., Athayde, C. C., Machado, H. L. and Lanzieri, P. G. (2013) Estetoscópio digital como ferramenta inovadora no ensino da ausculta cardíaca. *Arquivos Brasileiros de Cardiologia*, v. 100, n. 2, p. 187-189.

Melo, F. N. P. and Damasceno, M. M. C. (2006) A construção de um software educativo sobre ausculta dos sons respiratórios. *Revista da Escola de Enfermagem da USP*, v. 40, n. 4, p. 563-569, 2006.

Moroney, L. and Moroney, A. (2017) *Definitive Guide to Firebase*. Apress.

Novick, V. (2017). *React Native-Building Mobile Apps with JavaScript.* Packt Publishing Ltd.

Silva, P. M. B, Lopes, R. D. and Lopes, A. C. (2018) *Semiologia Cardiovascular: Baseada em Evidencias*, 1. ed. Rio de Janeiro: Editora Atheneu.

Stergiou, C., Psannis, K. E., Kim, B. G. and Gupta, B. (2018). Secure integration of IoT and cloud computing. *Future Generation Computer Systems*, 78, 964-975.

Appendix I - Screenshots of application screens (part 1)

Screen 1

Screen 2

Screen 3

Screen 4

Screen 5

Screen 6

Source: Authors, 2021

Appendix I - Screenshots of application screens (part 2)

Screen 7

Screen 8

Source: Authors, 2021